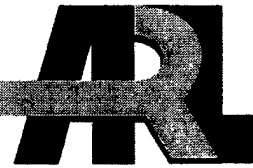


Army Research Laboratory



Scene and Countermeasure Integration for Munition Interaction with Targets Interim Report

By

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13. ABSTRACT (Maximum 200 words) Scene and Countermeasure Integration for Munition Interaction with Targets (SCIMITAR) is a model that brings real-world accuracy to your analysis. This is accomplished by integrating weather, smoke, and decoy models into a scene-based model. Smoke models or decoys often are narrowly focused on specific aspects of the decoy or smoke efficiency. For example, a smoke model is focused on prediction of transport and predictions of spectral transmission coefficients. SCIMITAR incorporates these aspects also, but goes one step further, and determines the interaction of the smoke or decoy with the background scene. The background scene is composed of a clutter background with targets placed into that background. To this background scene, smoke, decoys, and weather effects are integrated by use of physical models that determine actual effects that occur between the background and weather, decoys, or smokes. The model is currently being used by Survivability/Lethality Analysis Directorate analyst to evaluate obscurant, decoy, and signature suppression effects upon smart munitions and ground systems aimpoint and detection. The model now includes limited smokes and decoys. Weather will be incorporated in the future.				
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Preface

This report documents the simulation tool being developed by the U.S. Army Research Laboratory (ARL), Survivability/Lethality Analysis Directorate (SLAD) to analyze obscurant, decoy, and signature suppression effects on smart munitions and ground platforms. The work is funded with ARL/SLAD 6.2 funds and development is performed in-house. The planned development schedule is 3 years, and the program is currently in the second year of development. The tool is being developed primarily to meet requirements of independent evaluators and SLAD analysts.

Contents

Preface.....	1
Executive Summary	5
1. Introduction.....	7
1.1 Goal and Objective.....	7
1.2 Overview.....	7
2. Submodel Integration.....	11
3. Model Examples	13
3.1 COMBIC Output	13
3.2 Scene Generation and Target Placement	16
3.3 Linking COMBIC to the Scene.....	16
3.4 Detection and Aimpoint	19
4. Modeling Focus	25
5. Limitations	27
6. Conclusions	29
Acronyms	31
Distribution.....	33

Figures

1. Comparison of sensor-based modeling to scene-based modeling.....	9
2. Submodel integration.....	12
3. Setup geometry tool for smoke sources.....	14
4. Color-coded smoke cloud transmission	14
5. Old version of COMBIC.....	15
6. MMW scene-generation, user interface window	17
7. MMW scene zoomed in around target area.....	17
8. IR scene-generation, user interface window with 195 X 265 m meadow clutter with one target at center of scene	18
9. IR scene zoomed in around target area	18
10. Smoke cloud linked to a scene	21
11. Background scene temperature (degrees centigrade)	22
12. COMBIC smoke cloud concentration (g/cm ³).....	22
13. Combined scene/cloud temperature (degrees centigrade)	22
14. IR image of a 2S-3 Howitzer under a net canopy, with predicted aimpoint shown	23
15. Aimpoint detection pixels from 2S-3 target under a net canopy, along with predicted aimpoint	23

Executive Summary

Introduction

The U.S. Army Research Laboratory (ARL) Survivability/Lethality Analysis Directorate (SLAD) needed a better way to analyze obscurant, decoy, and signature suppression effects on smart munitions and ground platforms at the system level. It was recognized that knowing the transmission through a smoke cloud, or measuring a suppressed target signature, was insufficient to determine the effect of these countermeasures on a system. Therefore, SLAD embarked on a program to integrate several existing sub-models. This integration effort has made significant progress towards modeling synergistic countermeasures such as decoys, target suppression, and obscurants in the background clutter, weather, and atmosphere that they typically operate in. The countermeasure effects upon seekers or sensors are addressed by modeling detection, aimpoint, and hitpoint. These are provided as an input to lethality functions.

Goal and Objective

The goal is to deliver a user friendly tool to the SLAD analyst responsible for performing countermeasures analysis of U.S. Army weapon systems.

The objective is to evaluate obscurant, decoy, and signature suppression effects upon smart munitions and ground platforms at a system level. This objective is achieved by developing a link between countermeasures and ballistics analysis, using a scene-based analysis tool.

Overview

A conscious decision was made to develop a scene-based model as opposed to a sensor-based model. There were two reasons for this decision.

- The first reason is that the submodels necessary to develop the scene-based model were by and large already available to the development team.
- The second reason is the driving requirement of the SLAD analyst.

The analyst evaluates system performance as a function of environment, which the scene-based model is ideally suited for. Scene-based models and sensor-based models tend to perform complimentary functions. The sensor-based model does an excellent job of evaluating sensor hardware; however, it has less utility evaluating sensor performance as a function of environment than the scene-based model.

Conclusions

After 1-1/2 years of development effort, the model is sufficiently mature to predict seeker detection and aimpoint for specific systems. Version 1 of the clutter model is complete for infrared and millimeter wavelengths. Targets with suppressed signatures can be placed in the scene. A model to predict obscurant transmission and transport/diffusion is integrated with the scene model.

The information generated by the model has shown that integrated, scene-based modeling yields in-depth knowledge of munitions and ground system performance in the presence of obscurants, decoys, and signature suppression countermeasures.

1. Introduction

The U.S. Army Research Laboratory (ARL) Survivability/Lethality Analysis Directorate (SLAD) needed a better way to analyze obscurant, decoy, and signature suppression effects upon smart munitions and ground platforms at the system level. It was recognized that knowing the transmission through a smoke cloud, or measuring a target signature, was insufficient to determine the effect of these countermeasures on a system. Therefore, SLAD embarked upon a program to integrate several existing submodels. This integration effort has made significant progress towards modeling synergistic countermeasures such as decoys, target suppression, and obscurants in the background clutter, weather, and atmosphere that they typically operate in. The countermeasure effects upon seekers or sensors are addressed by modeling detection and aimpoint.

1.1 Goal and Objective

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The objective is to evaluate obscurant, decoy, and signature suppression effects upon smart munitions and ground platforms at a system level. This objective is achieved by developing a link between countermeasures and ballistics analysis using a scene-based analysis tool.

1.2 Overview

A conscious decision was made to develop a scene-based model as opposed to a sensor-based model. There were two reasons for this decision.

- The first reason is that the submodels necessary to develop the scene-based model were by and large already available to the development team.

- The second reason is that the driving requirement for the prime user of the tool, the SLAD analyst, was to evaluate system performance as a function of environment; the scene-based model is ideally suited to meet this requirement.

Scene-based models and sensor-based models tend to perform complimentary functions. The sensor-based model does an excellent job of evaluating sensor hardware; however, it has less utility evaluating sensor performance as a function of environment than the scene-based model. Figure 1 compares scene-based modeling to sensor-based modeling. It demonstrates how all components of the operational environment impact the bottom line, which is lethality (when considering seekers with warheads) or vulnerability (when considering ground platforms).

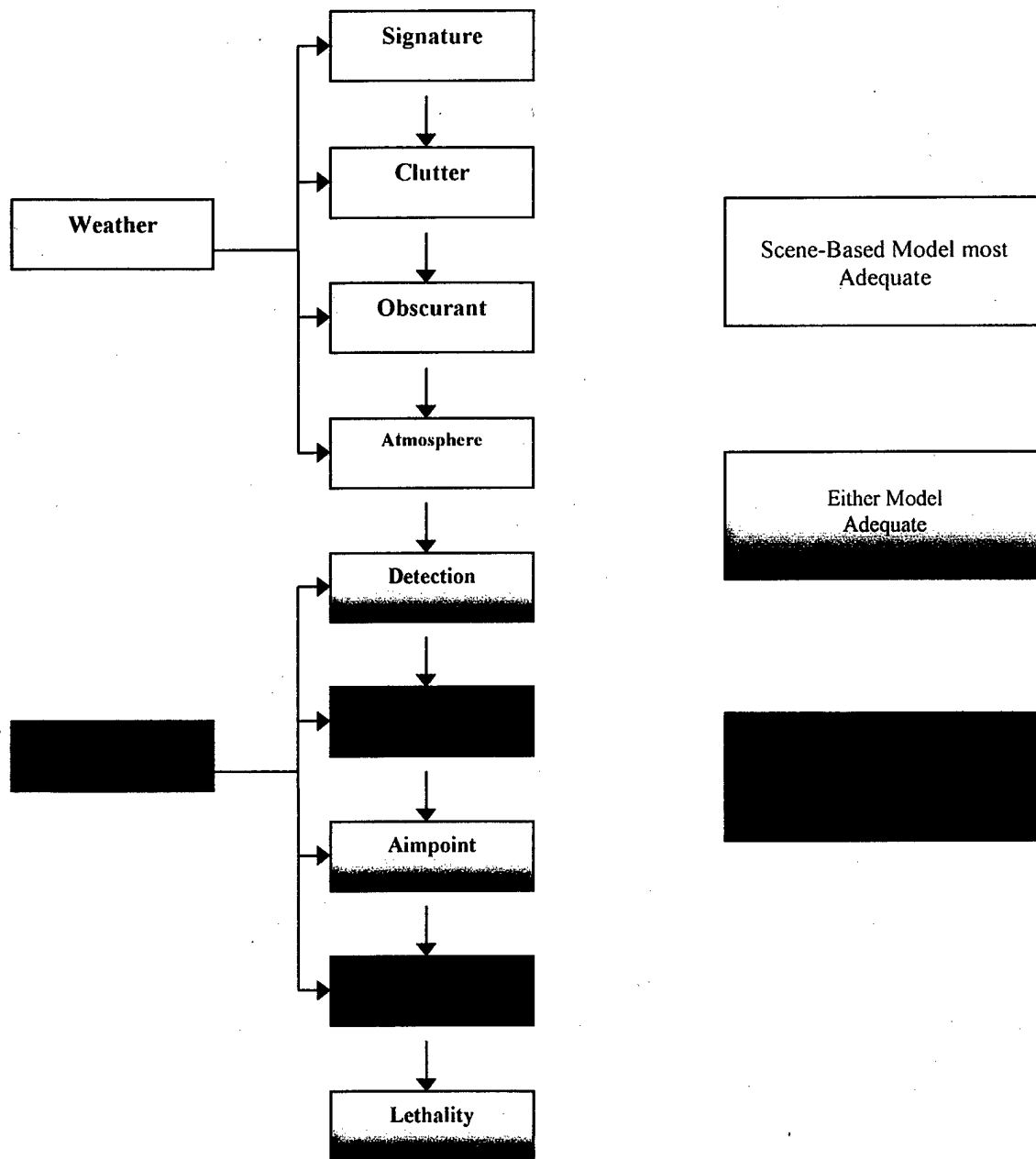


Figure 1. Comparison of sensor-based modeling to scene-based modeling.

2. Submodel Integration

Several models and submodels were already available to the model developers. The main development task is to integrate the submodels together, thus providing a cohesive analysis tool to analyze system level effects upon sensors and ground platforms. This integration has required rewriting some of the submodels and developing others to provide meaningful results from the integrated analysis tool.

Detection and aimpoint models comprise the sensor module. The detection and aimpoint models are fairly generic in nature, but some customization is necessary to adapt them to specific sensors. At this stage in development, initial aimpoint and detection models are completed and linked to the scene.

The Combined Obscuration Model for Battlefield Induced Contaminants (COMBIC) quantifies the effects of obscurants on transmission of the visible through infrared (IR) wavelengths. This simulation, developed by the former U.S. Army Atmospheric Science Laboratory, predicts spatial and temporal variation in transmission produced by various munitions and vehicles, and determines the effect on electro-optical (EO) sensors. COMBIC allows a user-defined scenario of smoke and dust sources to be built. Several enhancements have been added to COMBIC to improve utility.

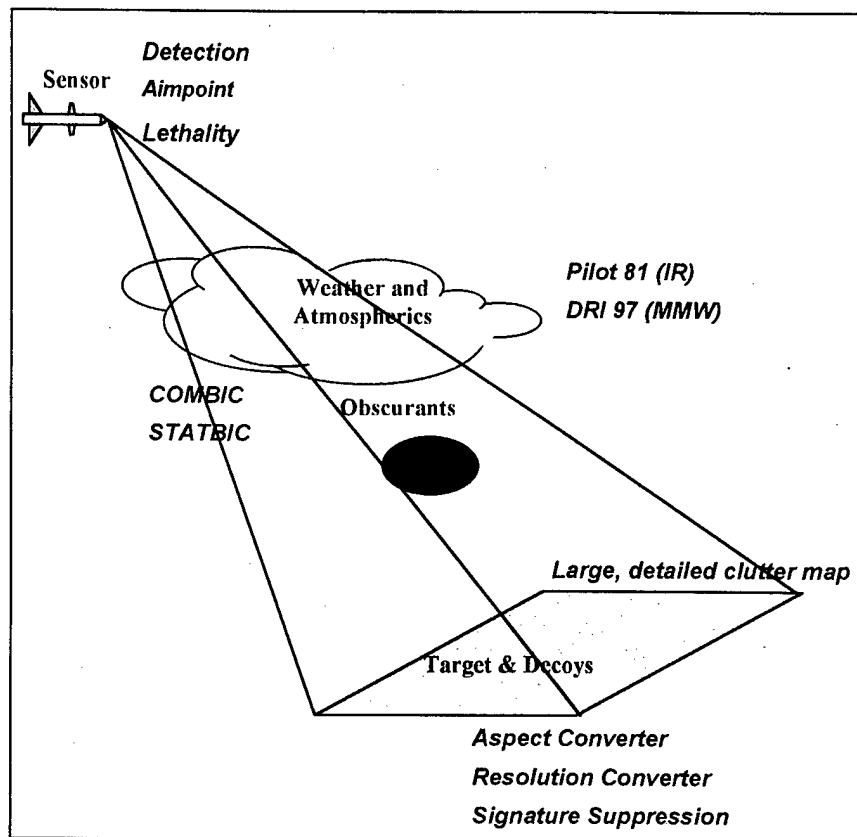
The scene model is composed of a large, detailed clutter map representing measured IR and millimeter wavelengths (MMW) clutter. A large target database, composed of clean and suppressed targets, is available and is being expanded to include more targets and decoys. At this point, targets can be placed and manipulated on the clutter map.

PILOT81 and DRI 97 are atmospheric propagation models that are being developed to integrate backgrounds and obscurant effects.

- PILOT 81 predicts atmospheric self-radiance and scattering at IR wavelengths.
- DRI 97 predicts atmospheric scattering MMW.

Although some further development of the submodels is ongoing, the inter-relationships of the primary submodels are depicted in figure 2.

Figure 2. Submodel integration.



3. Model Examples

This section shows some illustrative examples of model outputs. The figures are primarily computer monitor screen dumps from actual model runs.

3.1 COMBIC Output

The COMBIC model quantifies the effects of obscurants on transmission of the visible through IR wavelengths. COMBIC requires the user to input weather factors and various obscurant properties and to place the obscurant in the scene and to set up the observer line of sight.

Figure 3 is a screen dump from the model showing the tool to set up placement of some smoke grenades relative to an observer line of sight. This tool is a three-dimensional tool that can be rotated to enable the user to better visualize the scenario.

Figure 4 is a map depicting transmission through a smoke cloud, caused by a volley of smoke grenades. At this point in time, COMBIC is configured to handle visual, IR, or MMW transmission. An additional feature has been added to COMBIC enabling the user to step through time and watch the cloud progress across a scene or play back a movie showing the cloud transport. The spike protruding from the lower left corner of the cloud in figure 4 was caused by one of the smoke grenades that was separated from the other grenades. This can be visualized in figure 3 as a red dot that is separated from the other red dots.

Several improvements have been made to COMBIC including better visualization, easier setup, and time variation, as well as linkage to a clutter scene, atmospheric model, and sensor model. Figure 5 is an example of the old COMBIC output, in which transmission values were depicted by different symbols. Figure 5 is included to illustrate the improvements made to COMBIC.

Figure 3. Setup geometry tool for smoke sources.

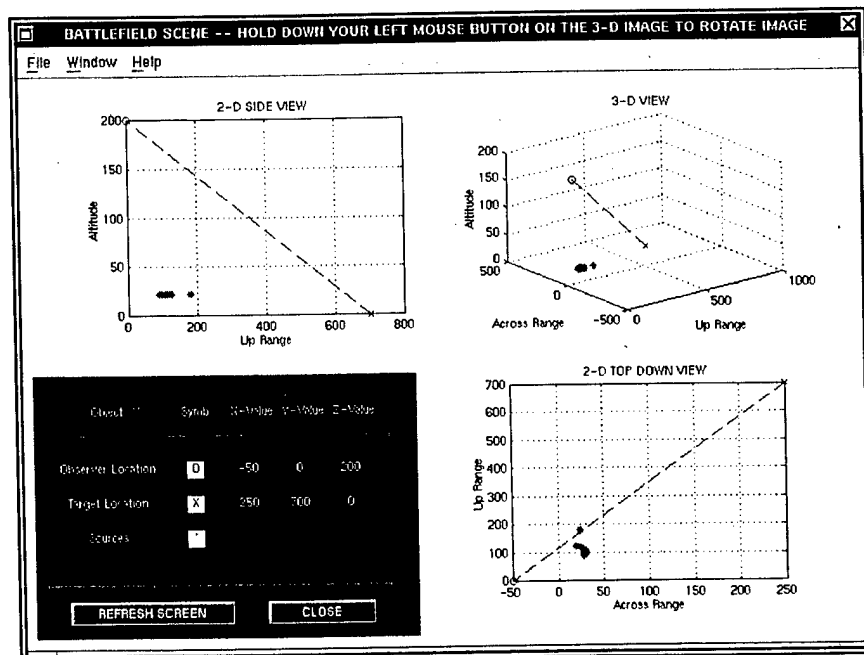


Figure 4. Color-coded smoke cloud transmission.

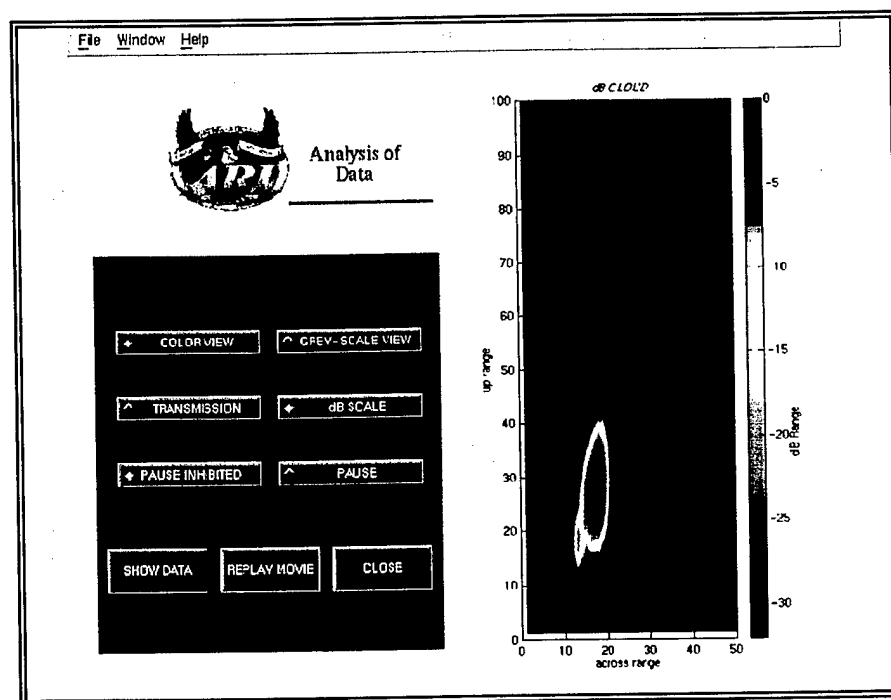
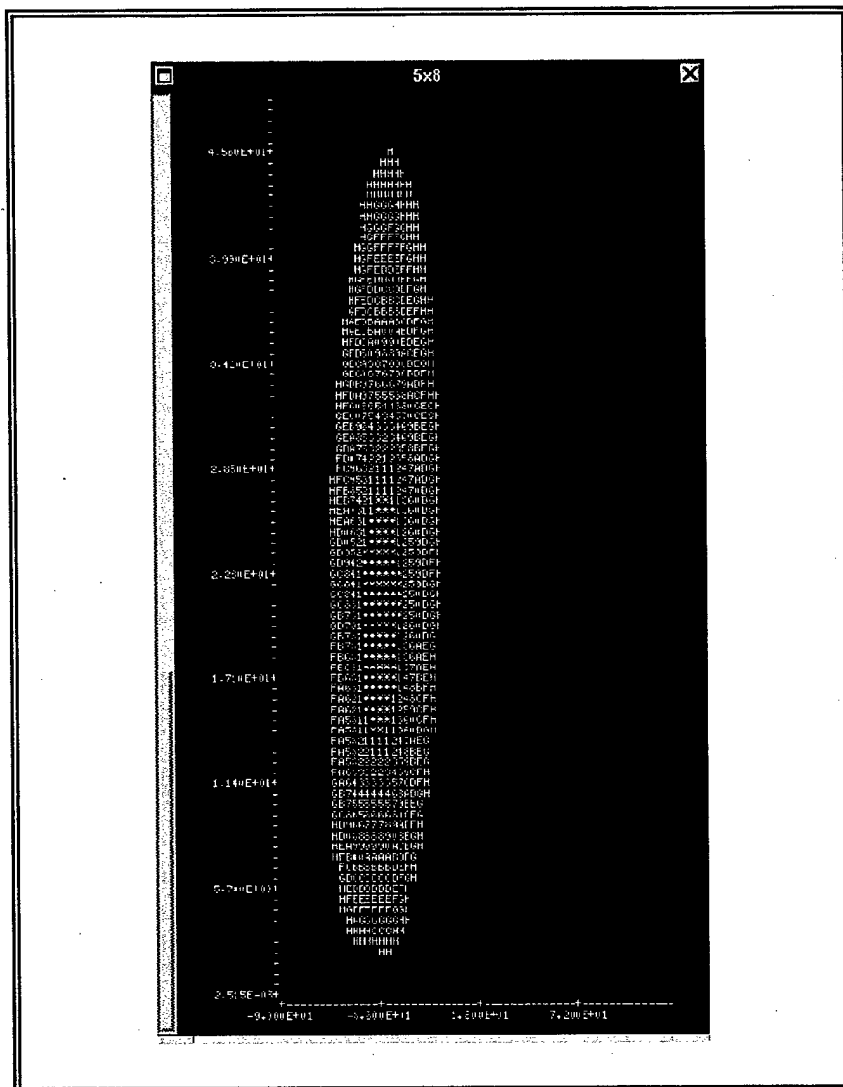


Figure 5. Old version of COMBIC.



3.2 Scene Generation and Target Placement

The model is currently set up to model both MMW radar and IR clutter scenes. Both the clutter and the target data begin as high resolution, measured data and are then degraded in resolution to match the system being evaluated.

Many of the clutter scenes originate from a measurement space that is smaller than the modeled scene. This is done by randomly mapping the measured clutter distribution onto the scene. The advantage of this is that larger clutter scenes can be modeled. The disadvantage is that spatial relationships between clutter cells are lost. However, if measured data is available for large clutter areas, these can be mapped directly onto the scene without loss of spatial relationships. Within the scene, various clutter subtypes can be modeled, such as trees, roads, lakes, ravines, etc.

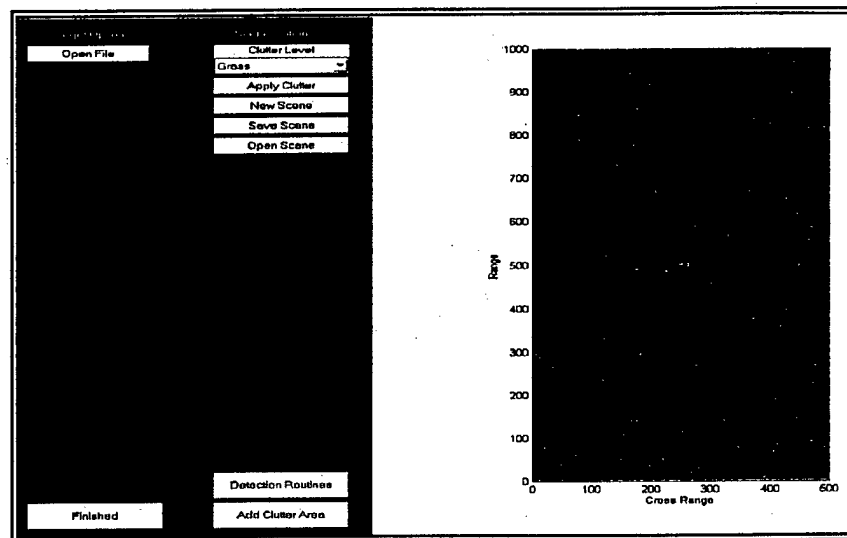
The targets are placed onto the scene using various placement tools available to the user. Figure 6 is an example of the scene- and target-generation, user interface window together with an actual MMW radar clutter scene. Figure 7 is the same scene, zoomed in around the target area.

Figure 8 is an example of the scene- and target-generation, user interface window and with an actual IR clutter scene. Figure 9 is the same scene, zoomed in around the target area.

3.3 Linking COMBIC to the Scene

An integral and important part of the model is linking the transport/diffusion model to the clutter/target scene. The MMW integration is illustrated below. The MMW algorithm currently models only transmission reduction through the cloud, but does not model the radiance and scattering within the cloud because DRI 97 is not presently integrated.

Figure 6. MMW scene-generation, user interface window.



Note: 500 X 1000 m meadow clutter with two targets at center of scene.

Figure 7. MMW scene zoomed in around target area.

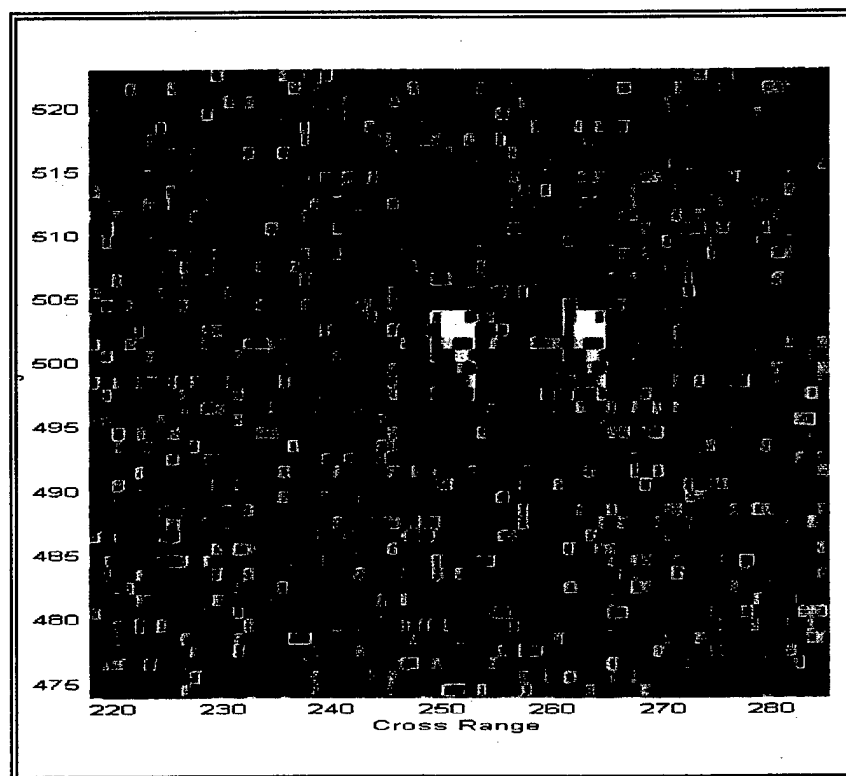


Figure 8. IR scene-generation, user interface window with 195 X 265 m meadow clutter with one target at center of scene.

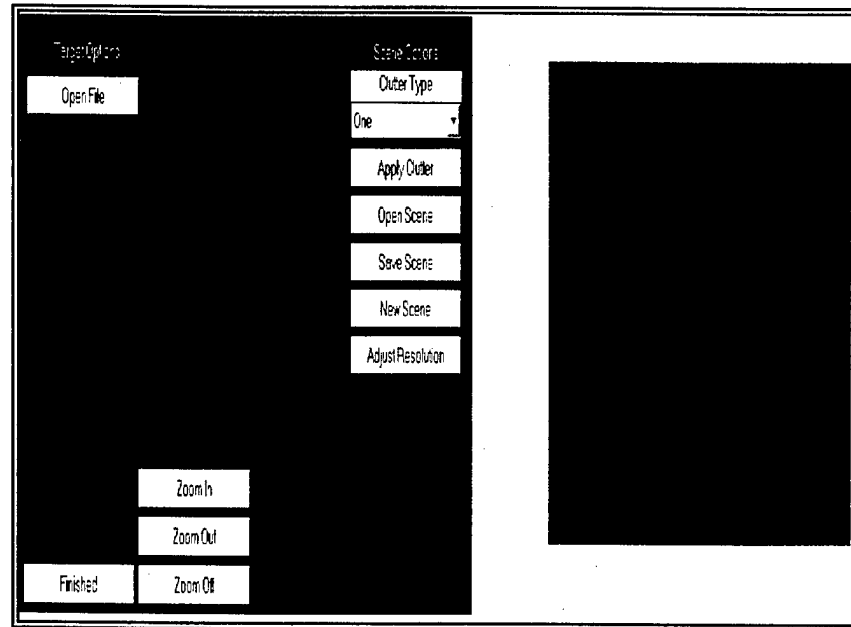


Figure 9. IR scene zoomed in around target area.

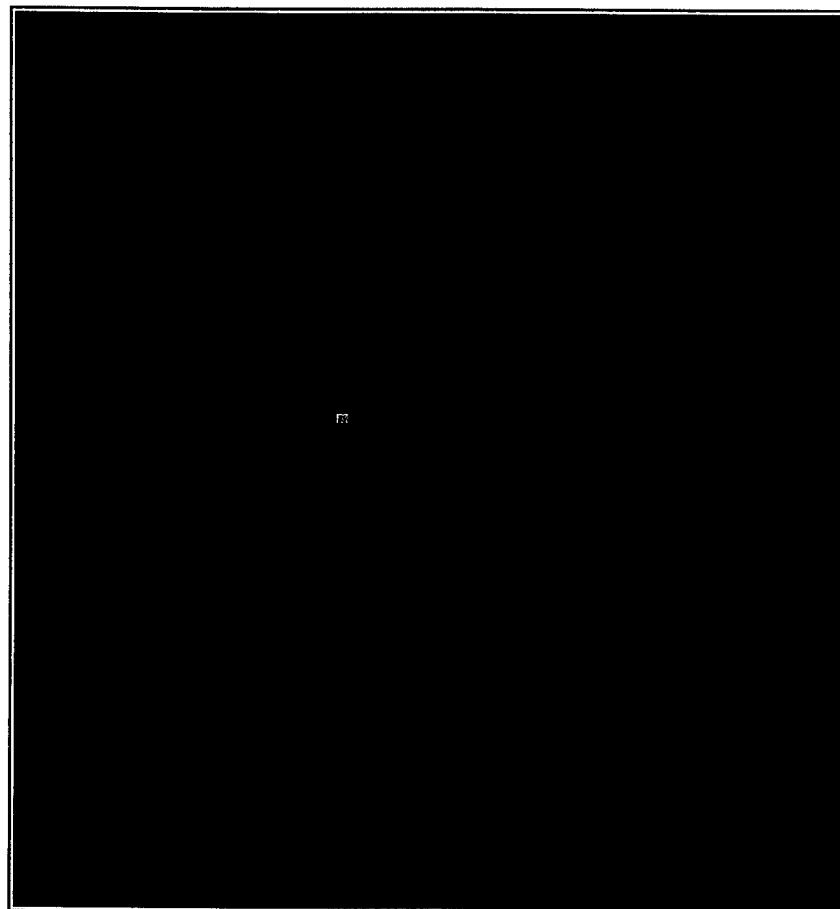


Figure 10 illustrates a snapshot of a cloud at the verge of drifting over a target. On the computer, one may playback a movie showing the cloud drifting over the target.

The IR clutter/target scene is linked with weather effects and aerosol/concentration array via the PILOT81 model. This model starts with a "clean" IR scene and a smoke concentration cloud from COMBIC. Applying radiative boundary conditions consistent with the environmental scenario to "degrade" the scene combines the smoke cloud and background scenes.

PILOT81 goes beyond COMBIC, modeling cloud radiance and scattering through the cloud. These are two important factors not modeled in COMBIC. By using PILOT81 to integrate the scene and the smoke cloud, a more valid solution is provided than the solution provided by COMBIC alone. Figures 11 through 13 illustrate this integration.

3.4 Detection and Aimpoint

Several algorithms are available and integrated into the model to predict seeker detection of a target given a particular clutter scene. The detection algorithm is nonparametric with different threshold levels and seeker scan patterns.

Aimpoints are calculated based on a weighted centroid method. As this model does not simulate a six degrees of freedom (6DOF) airframe model for the seeker, a closed loop solution is not calculated. Instead, a distribution about an aimpoint is used to derive hitpoint from aimpoint. This information is then passed to the SLAD Ballistics & NBC Division (BND) for lethality determination.

Sensitivity analysis comparing this model to measured results has shown that the dominant factors critical to model aimpoint are:

- high quality signature data,
- the ability to place the target next to discrete terrain features, and
- a knowledge of basic sensor characteristics.

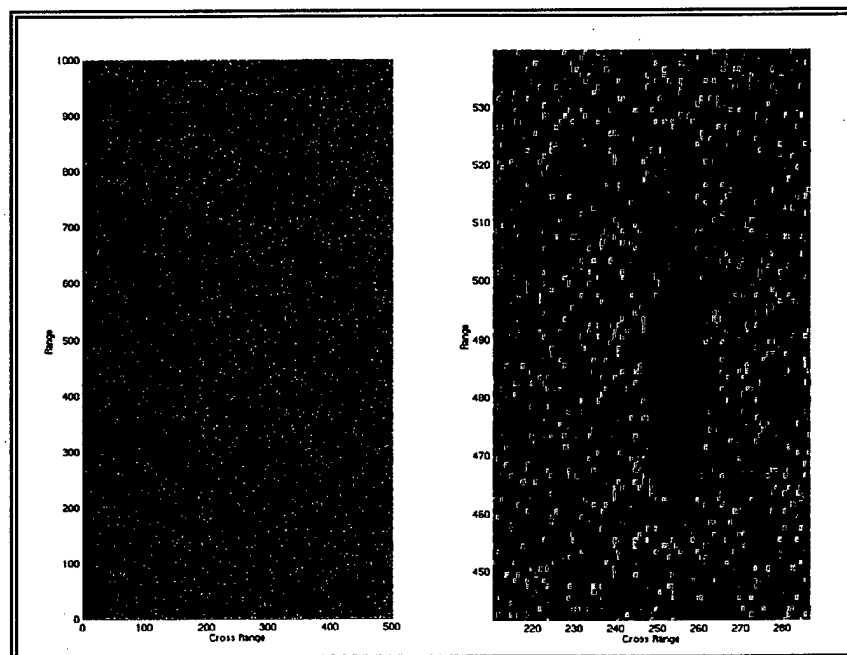
The required sensor characteristics are:

- wavelength of operation,
- spatial resolution (whether positive and/or negative thresholds are used),
- operational range,
- search patterns, and
- look-down angle.

It is important to point out that highly specific sensor characteristics were not required to make reasonably accurate aimpoint predictions.

Figure 14 shows target pixels (which were detected using a dual threshold algorithm) a centroid mapping, and a target-sizing algorithm for the aimpoint. Figure 15 is a gray-scale representation of the target in figure 14 as seen at a specific sensor resolution.

Figure 10. Smoke cloud linked to a scene.



Note: The left image is a target at the center of a meadow with a smoke cloud drifting over. The right image is zoomed in.

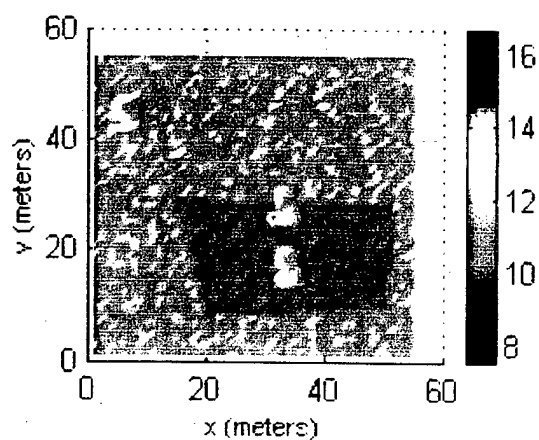


Figure 11. Background scene temperature (degrees centigrade).

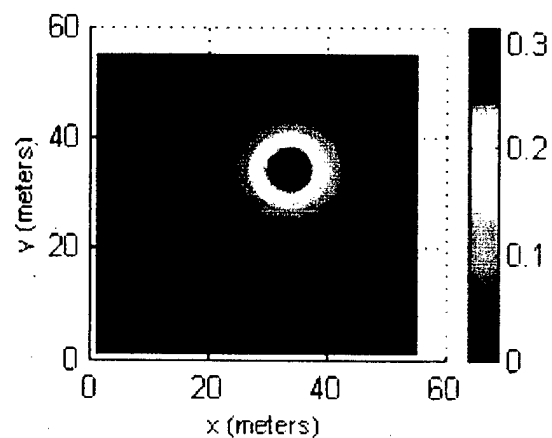


Figure 12. COMBIC smoke cloud concentration (g/cm³).

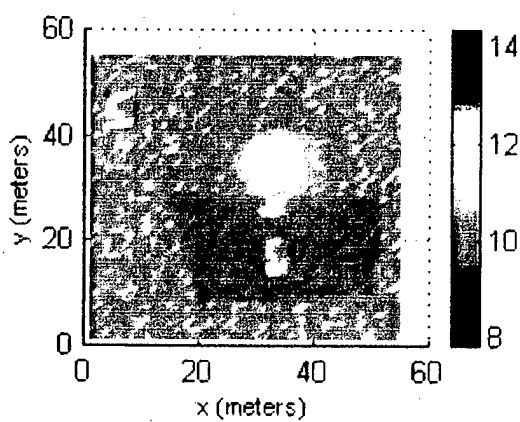


Figure 13. Combined scene/cloud temperature (degrees centigrade).

Figure 14. IR image of a 2S-3 Howitzer under a net canopy, with predicted aimpoint shown.

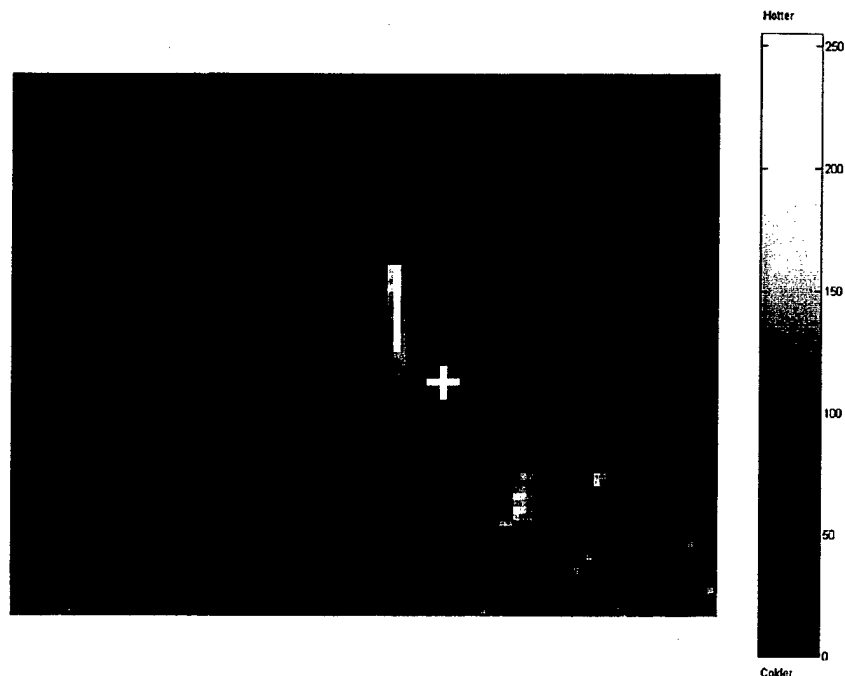
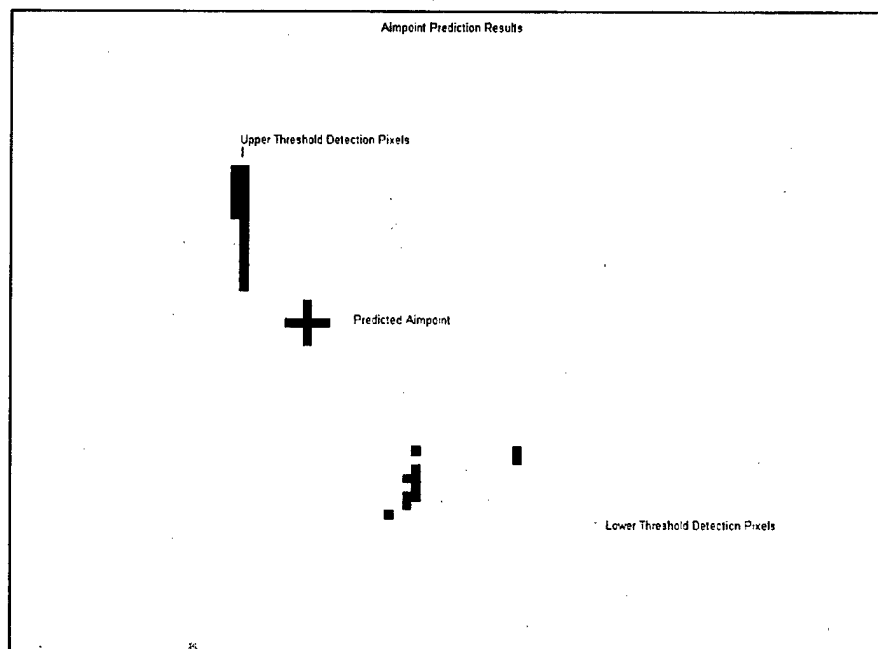


Figure 15. Aimpoint detection pixels from 2S-3 target under a net canopy, along with predicted aimpoint.



4. Modeling Focus

This model is in the 2^d yr of a planned 3-yr development effort. It is capable of performing many of the analysis functions required by the users. Present improvements include:

- more complex clutter scenes,
- integrated radiance and scattering algorithms for the IR obscurant clouds,
- improved resolution converter to make the model more flexible,
- and more sophisticated aimpoint calculations.

Long-term efforts will focus on:

- enlarging the target and clutter library,
- adding three-dimensional analysis techniques,
- performing verification experiments,
- comparing predicted results with measured data, and
- providing aimpoint predictions for ARL/SLAD/BND lethality determination.

5. Limitations

The following limitations are currently present in the design of this model. Some limitations are inherent in the architecture (such as lack of 6DOF), while others are a product of the stage-of-model development.

1. A 6DOF seeker model is not implemented. Hitpoint is modeled as a distribution about an aimpoint. In many cases, it is believed that this scene-based approach will predict hitpoint more accurately than a sensor-based approach with 6DOF, because the signature, clutter, weather, atmosphere, and obscurant affect hitpoint accuracy more than the 6DOF.
2. Countermeasures that attack the closed loop guidance (create breaklock or unstable track conditions) are not modeled.
3. Although clutter, atmosphere, and signature are common to most applications, some customization is necessary to account for sensor specifics, such as resolution and search angle.
4. Many submodels are not yet verified and validated. An in-depth model development phase is planned to accomplish this requirement.

6. Conclusions

After a 1-1/2 yr of development effort, the model is sufficiently mature to predict seeker detection and aimpoint. A clutter model is complete for IR and MMW. Targets with suppressed signatures can be placed in the scene. A model to predict obscurant transmission and transport/diffusion is integrated with the scene model. The present version of the model is version 1.

The information generated by the model has shown that integrated, scene-based modeling yields in-depth knowledge of munitions and ground system performance in the presence of obscurants, decoys, and signature suppression countermeasures.

Acronyms

6DOF	six degrees of freedom
ARL	U.S. Army Research Laboratory
BND	Ballistics & NBC Division
COMBIC	Combined Obscuration Model for Battlefield Induced Contaminants
EO	electro-optical
IR	infrared
MMW	millimeter wavelengths
SLAD	Survivability/Lethality Analysis Directorate

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